Designation: A 213/A 213M – 01a

An American National Standard
Used in USDOE-NE standards

Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes[1]

This standard is issued under the fixed designation A 213/A 213M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification[2] covers minimum-wall-thickness, seamless ferritic and austenitic steel, boiler and superheater tubes and austenitic steel heat-exchanger tubes, designated Grades T5, TP304, etc. These steels are listed in Table 1.

1.2 Grades S30432, TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP310HCbN, TP316H, TP321H, TP347H, TP347HFG (fine grained) and TP348H are modifications of Grades TP304, TP309S, TP309Cb, TP310S, TP310Cb, TP316, TP321, TP347, and TP348, and are intended for high-temperature service, such as for superheaters and reheaters.

1.3 The tubing sizes and thicknesses usually furnished to this specification are ⅛ in. [3.2 mm] in inside diameter to 5 in. [127 mm] in outside diameter and 0.015 to 0.500 in. [0.4 to 12.7 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.4 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.5 Optional supplementary requirements are provided and, when desired, shall be so stated in the order.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[3]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[4]

E 112 Test Methods for Determining Average Grain Size[5]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

2.2 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[6]

3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (seamless tubes),

3.1.3 Grade (Table 1 and Table 2),

3.1.4 Manufacture (hot finished or cold finished),

3.1.5 Controlled structural characteristics (see 6.2),

3.1.6 Size (outside diameter and minimum wall thickness),

3.1.7 Length (specific or random),

3.1.8 Hydrostatic Test or Nondestructive Electric Test (see 12.1),

3.1.9 Specification designation, and

3.1.10 Special requirements and any supplementary requirements selected.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 Tubes shall be made by the seamless process and shall be either hot finished or cold finished, as specified. Grade TP347HFG shall be cold finished.

5.2 *Grain Size*:

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[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Stainless and Alloy Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-213 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

TABLE 1 Chemical Requirements for Ferritic Steel

Grade	Composition, %									Other Elements
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Titanium	Vanadium, min	
T2[A]	0.10–0.20	0.30–0.61	0.025	0.025	0.10–0.30	0.50–0.81	0.44–0.65	...	...	
T5	0.15 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	...	...	
T5b	0.15 max	0.30–0.60	0.025	0.025	1.00–2.00	4.00–6.00	0.45–0.65	...	...	
T5c	0.12 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	[B]	...	
T9	0.15 max	0.30–0.60	0.025	0.025	0.25–1.00	8.00–10.00	0.90–1.10	...	...	
T11	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50–1.00	1.00–1.50	0.44–0.65	...	...	
T12[A]	0.05 min–0.15 max	0.30–0.61	0.025	0.025	0.50 max	0.80–1.25	0.44–0.65	...	...	
T17	0.15–0.25	0.30–0.61	0.025	0.025	0.15–0.35	0.80–1.25	...	...	0.15	
T21	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50 max	2.65–3.35	0.80–1.06	...	...	
T22	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50 max	1.90–2.60	0.87–1.13	...	...	
T23	0.04-0.10	0.10–0.60	0.030	0.010	0.50 max	1.90-2.60	0.05-0.30	...	0.20-0.30	W 1.45-1.75 Cb 0.02-0.08 B 0.0005-0.006 N 0.030 max Al 0.030 max
T24	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45	2.20–2.60	0.70–1.10	0.06–0.10	0.20–0.30	B 0.0015–0.0020 N 0.012 max Al 0.020 max
T91	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.00–9.50	0.85–1.05	...	0.18–0.25	Cb 0.06–0.1 N 0.030–0.070 Ni 0.40 max Al 0.04 max
T92	0.07–0.13	0.30–0.60	0.020	0.010	0.50 max	8.50–9.50	0.30–0.60	. . .	0.15–0.25	W 1.5–2.00 Cb 0.04–0.09 B 0.001–0.006 N 0.03–0.07 Ni 0.40 max Al 0.04 max
T122	0.07-0.14	0.70 max	0.020	0.010	0.50 max	10.00-12.50	0.25-0.60	...	0.15-0.30	W 1.50-2.50 Cu 0.30-1.70 Cb 0.04-0.10 B 0.0005-0.005 N 0.040-0.100 Ni 0.50 max Al 0.040 max
T911	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	8.50–10.50	0.90–1.10	...	0.18–0.25	Ni 0.40 max Cb 0.060–0.10 B 0.0003–0.006 N 0.04–0.09 Al 0.04 max W 0.90–1.10
18Cr-2Mo	0.025 max	1.00 max	0.040	0.030	1.00 max	17.5–19.5	1.75–2.50	[C]	...	N max 0.035 Ni + Cu max 1.00

[A] It is permissible to order T2 and T12 with 0.045 max Sulfur.
[B] Grade T5c shall have a titanium content of not less than four times the carbon content and not more than 0.70 %.
[C] Grade 18Cr-2Mo shall have Ti + Cb = 0.20 + 4 (C + N) min, 0.80 max.

5.2.1 The grain size of Grades 304H, 316H, 321H, 347H, 348H, and 310HCbN, as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

5.2.2 The grain size of cold-worked Grade TP321H, as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

5.2.3 The grain size of TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E 112, shall be No. 6 or coarser.

5.2.4 The grain size or cold-worked Grade TP347HFG as determined in accordance with Test Methods E 112 shall be between No. 7 and No. 10.

6. Heat Treatment

6.1 All tubes of grades shown in Table 1, except T5c, T23, T24, T91, T92, T122, and T911, and in accordance with 6.1.1 shall be reheated and furnished in the full-annealed, isothermal annealed, or normalized and tempered condition. If furnished in the normalized and tempered condition, the minimum tempering temperature for Grades T5, T5b, T9, T21, and T22 shall be 1250°F [675°C], and the minimum tempering temperature for Grades T11 and T17 shall be 1200°F [650°C].

6.1.1 Tubing of Grades T2 and T12 either hot-finished or cold-drawn, may be given a final heat treatment at 1200 to 1350°F [650 to 730°C] instead of heat treatments specified in 6.1 at the option of the manufacturer.

6.1.2 All tubing of Grade T5c shall be given a final heat treatment of approximately 1350°F [730°C] for a proper time, followed by air or furnace cooling.

6.1.3 Grade T24 shall be normalized at 1800°F [980°C]

minimum and tempered at 1350°F [730°C] minimum as a final heat treatment.

6.1.4 Grades T23, T91, T92, T122, and T911 shall be normalized at 1900°F [1040°C] minimum and tempered at 1350°F [730°C] minimum as a final heat treatment.

NOTE 1—Isothermal annealing as applied to tubular products, may involve austenitizing a ferrous alloy and then cooling to and holding within the range of temperature at which austenite transforms to a relatively soft ferrite-carbide aggregate.

6.2 If any controlled structural characteristics are required these shall be so specified as to be a guide as to the most suitable heat treatment.

6.3 All austenitic tubes shall be furnished in the heat-treated condition. The heat-treatment procedure, except for the H grades and S30815, shall consist of heating the material to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means. Alternatively, immediately following hot forming, while the temperature of the tubes is not less than the specified minimum solution treatment temperature, tubes may be individually quenched in water or rapidly cooled by other means.

6.4 All H, S30815, S33228, and S31272 grades shall be furnished in the solution-treated condition. If cold working is involved in processing, the minimum solution treating temperature for Grades TP321H, TP347H and TP348H shall be 2000°F [1100°C] and for Grades TP304H, and TP316H, 1900°F [1040°C]. If the H grade is hot-rolled, the minimum solution treatment for Grades TP321H, TP347H, and TP348H shall be 1925°F [1050°C], and for Grades TP304H, and TP316H, 1900°F [1040°C]. The minimum solution treating temperature for S30815 and S31272 shall be 1920°F [1050°C]. The minimum solution treating temperature for S33228 shall be 2050°F [1120°C]. The minimum solution treating temperature for TP309H, TP309HCb, TP310H, and TP310HCb shall be 1900°F [1037°C]. The minimum solution treating temperature for TP310HCbN shall be 2000°F (1100°C) and sufficient to produce a grain size of No. 7 or coarser. The minimum solution treating temperature for S30432 shall be 2000°F [1100°C].

6.5 The heat treatment of cold-worked TP347HFG comprises a softening heat treatment prior to cold-working, and a solution heat treatment after final cold-working. The softening temperature shall be at least 90°F [50°C] higher than the solution heat treatment temperature which shall be at 2150°F [1180°C] minimum.

6.6 Tubing of Grade 18Cr-2Mo shall be given a final heat treatment of 1400°F [760°C] or higher, and cooled in such a manner as to meet the requirements of this specification.

6.7 The minimum solution treating temperature for grade UNS S21500 shall be 1920°F [1050°C]. A maximum solution treating temperature of 2100°F [1150°C] is recommended.

6.8 S34565 shall be heat treated in the temperature range from 2050°F [1120°C] minimum to 2140°F [1170°C] maximum, followed by quenching in water or rapidly cooling by other means.

6.9 S32050 shall be heat treated to a minimum temperature of 2100°F [1150°C] followed by quenching in water or rapidly cooling by other means.

6.10 A solution annealing temperature above 1950°F [1065°C] may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP309HCb, TP310HCb, TP310HCbN, TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or resolution anneal shall be used subsequent to the initial high-temperature solution anneal (see Supplementary Requirement S2).

TABLE 2 Chemical Requirements of Austentic Steel

Grade	TP201	TP202	TP304	TP 304H	. . .	TP 304N	TP 304LN	TP 304L	TP 309Cb	TP 309H	TP 309HCb	TP 309S	. . .	TP 310Cb	TP 310H	TP 310HCb	TP 310HCbN	TP 310S		TP316	TP 316H
UNS Designation[A]	S20100	S20200	S30400	S30409	S30432	S30451	S30453	S30403	S30940	S30909	S30941	S30908	S31002	S31040	S31009	S31041	S31042	S31008	S31272	S31600	S31609
Carbon	0.15 max	0.15 max	0.08 max	0.04–0.10	0.07–0.13	0.08 max	0.035 max[B]	0.035 max[B]	0.08 max	0.04–0.10	0.04–0.10	0.08 max	0.015 max	0.08 max	0.04–0.10	0.04–0.10	0.04–0.10	0.08 max	0.08–0.12	0.08 max	0.04–0.10
Manganese, max	5.50–7.50	7.50–10.0	2.00	2.00	0.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.5–2.0	2.00	2.00
Phosphorus, max	0.060	0.060	0.040	0.040	0.045	0.040	0.040	0.040	0.045	0.045	0.045	0.045	0.020	0.045	0.040	0.045	0.030	0.045	0.030	0.040	0.040
Sulfur, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.015	0.030	0.030	0.030	0.030	0.030	0.015	0.030	0.030
Silicon	1.00 max	1.00 max	0.75 max	0.75 max	0.30 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.15 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.3–0.7	0.75 max	0.75 max
Nickel	3.50–5.50	4.00–6.00	8.00–11.0	8.00–11.0	7.50–10.50	8.00–11.0	8.00–11.0	8.00–13.0	12.00–16.00	12.00–15.00	12.00–16.00	12.00–15.00	19.0–22.0	19.00–22.00	19.0–22.00	19.0–22.00	17.00–23.00	19.00–22.00	14.0–16.0	11.0–14.0	11.0–14.0
Chromium	16.0–18.0	17.0–19.0	18.0–20.0	18.0–20.0	17.00–19.00	18.0–20.0	18.0–20.0	18.0–20.0	22.00–24.00	22.00–24.00	22.00–24.00	22.00–24.00	24.0–26.0	24.00–26.00	24.00–26.00	24.00–26.00	24.00–26.00	24.00–26.00	14.0–16.0	16.0–18.0	16.0–18.0
Molybdenum	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.75 max	0.75 max	0.75 max	0.75 max	0.10 max	0.75 max	. . .	0.75 max	. . .	0.75 max	1.0–1.4	2.00–3.00	2.00–3.00
Titanium		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.3–0.6	. . .	. . .
Columbium + tantalum	. . .	. . .	. . .	. . .	0.20–0.80	. . .	. . .	. . .	10× C min, 1.10 max	. . .	10 × C min, 1.10 max	. . .	. . .	10× C min, 1.10 max	. . .	10 × C min, 1.10 max	0.20–0.60	. . .	. . .	. . .	. . .
Tantalum, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Nitrogen[C]	0.25 max	0.25 max	. . .	. . .	0.05–0.12	0.10–0.16	0.10–0.16	. . .	. . .	. . .	. . .	. . .	0.10 max	. . .	. . .	. . .	0.15–0.35	. . .	. . .	. . .	. . .
Cerium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Others	. . .	. . .	. . .	. . .	B 0.001–0.010 Al 0.003–0.030 Cu 2.5–3.5	. . .	. . .	. . .		. . .			. . .		. . .		. . .		B 0.004–0.008	. . .	

TABLE 2 *Continued*

Grade	TP316L	TP316N	TP 316LN	TP317	TP317L	TP321	TP 321H	TP347	TP 347H	TP 347LN	TP 347HFG	TP348	TP 348H
UNS Designation [A]	S31603	S31651	S31653	S31700	S31703	S32100	S32109	S34700	S34709	S34751		S34800	S34809
Carbon	0.035 max[B]	0.08 max	0.035 max[B]	0.08 max	0.035 max	0.08 max	0.04–0.10	0.08 max	0.04–0.10	0.005–0.020	0.06–0.10	0.08 max	0.04–0.10
Manganese, max	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Phosphorus, max	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Sulfur, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Silicon	0.75 max[C]	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max
Nickel	10.0–15.0	11.0–14.0	11.0–14.0	11.0–14.0	11.0–15.0	9.00–13.0	9.00–13.0	9.00–13.0	9.00–13.0	9.0–13.0	9.00–13.0	9.00–13.0	9.00–13.0
Chromium	16.0–18.0	16.0–18.0	16.0–18.0	18.0–20.0	18.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0
Molybdenum	2.00–3.00	2.00–3.00	2.00–3.00	3.00–4.00	3.00–4.00	. . .	. . .	. . .	. . .	. . .		. . .	. . .
Titanium	. . .	. . .	. . .	. . .	. . .	[D]	[E]	. . .	. . .	. . .	. . .	. . .	. . .
Columbium + tantalum	. . .	. . .	. . .	. . .	. . .	. . .	. . .	[F]	[G]	0.2–0.5[H]	8×c–1.0	[F]	[G]
Tantalum, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		0.10	0.10
Nitrogen[I]	. . .	0.10–0.16	0.10–0.16	. . .	. . .	. . .	. . .	. . .	. . .	0.06–0.10		. . .	. . .
Cerium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		. . .	. . .
Others	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		. . .	. . .

TABLE 2 *Continued*

Grade	XM-15								. . .	XM-19	. . .	. . .	. . .
UNS Designation [A]	S38100	S30615	S30815	S31050	S21500	S31725	S31726	S32615	S33228	S20910	S25700	S32050	S34565
Carbon	0.08 max	0.016–0.24	0.05–0.10	0.025	0.06–0.15	0.03 max	0.03 max	0.07 max	0.04–0.08	0.06 max	0.02 max	0.030 max	0.030 max
Manganese, max	2.00	2.00	0.80	2.00	5.50–7.0	2.00	2.00	2.00	1.0	4.00–6.00	2.0	1.50	5.0–7.0
Phosphorus, max	0.030	0.03	0.040	0.020	0.040	0.040	0.040	0.045	0.020	0.04	0.025	0.035	0.030
Sulfur, max	0.030	0.03	0.030	0.015	0.030	0.030	0.030	0.030	0.015	0.03	0.010	0.020	0.010
Silicon	1.50–2.50	3.2-4.0	1.40 2.00	0.4	0.2–1.0	0.75	0.75	4.8-6.0	0.30	1.00 max	6.5–8.0	1.00 max	1.00 max
Nickel	17.5–18.5	13.5–16.0	10.0–12.0	20.5–23.5	9.00–11.0	13.5–17.5	13.5–17.5	19.0–22.0	31.0–33.0	11.5–13.5	22.0–25.0	20.0–22.0	16.0–18.0
Chromium	17.0–19.0	17.0–19.5	20.0–22.0	24.0–26.0	14.0–16.0	18.0–20.0	17.0–20.0	16.5–19.5	26.0–28.0	20.5–23.5	8.0–11.0	22.0–24.0	23.0–25.0
Molybdenum	. . .	. . .	. . .	1.6–2.6	0.8–1.20	4.0–5.00	4.0–5.00	0.3–1.5	. . .	1.50–3.00	0.50 max	6.0–6.8	4.0–5.0
Titanium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Columbium + tantalum	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.6–1.0	0.10–0.30	. . .	. . .	. . .
Tantalum, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Nitrogen [I]	. . .	. . .	0.14–0.20	0.09–0.15	. . .	0.10 max	0.10–0.20	. . .	. . .	0.20–0.40	. . .	0.21–0.32	0.40–0.60
Cerium	. . .	. . .	0.03–0.08	. . .	. . .	. . .	. . .	. . .	0.05–0.10	. . .	. . .	. . .	. . .
Others	. . .	Al 0.8–1.5	. . .		Cb 0.75–1.25 V 0.15–0.40 B 0.003–0.009	Cu 0.75 max	Cu 0.75 max	Cu 1.5–2.5	Al 0.025 max	V 0.10–0.30	. . .	Cu 0.40 max	Cb 0.10 max

[A] New designation established in accordance with Practice E 527 and SAE J1086.
[B] For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes are those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1.1 mm] in minimum wall thickess).
[C] For seamless TP316L tubes, the silicon maximum shall be 1.00 %.
[D] Grade TP321 shall have a titanium content of not less than five times the carbon content and not more than 0.60 %.
[E] Grade TP321H shall have a titanium content of not less than four times the carbon content and not more than 0.60 %.
[F] Grades TP347 and TP348 shall have a columbium plus tantalum content of not less than ten times the carbon content and not more than 1.00 %.
[G] Grades TP347H and TP348H shall have a columbium plus tantalum content of not less than eight times the carbon content and not more than 1.0 %.
[H] Grade TP347LN shall have a columbium (niobium) plus tantalum content of not less than 15 times the carbon content.
[I] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 and Table 2.

8. Product Analysis

8.1 An analysis of either one billet or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 For Grade T91 the carbon content may vary for the product analysis by −0.01 % and +0.02 % from the specified range as per Table 1.

8.3 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 2—For flattening, flaring, and grain size requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace or when heat-treated condition is obtained directly by quenching after hot forming, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 3.

NOTE 3—For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace or when heat-treated condition is obtained directly by quenching after hot forming, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed or all tubes of the same size and heat, hot formed and quenching in the same production run.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 4.

9.2 Table 5 gives the computed minimum elongation values for each 1/32-in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equations. For Grades 18Cr-2Mo, T24, T91, T92, and

TABLE 3 Number of Tubes in a Lot Heat Treated by the Continuous Process or by Direct Quench After Hot Forming

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
2 in. [50.8 mm] and over in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

TABLE 4 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %[A,B]
Ferritic Grades:				
T12	...	60[415]	32[220]	30
T23	...	74[510]	58[400]	20
T24	...	85[585]	60[415]	20
T91	...	85[585]	60[415]	20
T92	K92460	90[620]	64[440]	20
T122	...	90[620]	58[400]	20
T911	K91061	90[620]	64[440]	20
18Cr-2Mo	...	60[415]	40[275]	20
All other grades		60[415]	30[205]	30
Austenitic Grades:				
TP201	S20100	95[655]	38[260]	35
TP202	S20200	90[620]	45[310]	35
TP304	S30400	75[515]	30[205]	35
TP304H	S30409	75[515]	30[205]	35
...	S30432	80[550]	30[205]	35
TP304N	S30451	80[550]	35[240]	35
TP304L	S30403	70[485]	25[170]	35
TP304LN	S30453	75[515]	30[205]	35
TP309Cb	S30940	75[515]	30[205]	35
TP309H	S30909	75[515]	30[205]	35
TP309HCb	S30941	75[515]	30[205]	35
TP309S	S30908	75[515]	30[205]	35
...	S31002	73[500]	30[205]	35
TP310Cb	S31040	75[515]	30[205]	35
TP310H	S31009	75[515]	30[205]	35
TP310HCb	S31041	75[515]	30[205]	35
TP310HCbN	S31042	95[655]	43[295]	30
TP310S	S31008	75[515]	30[205]	35
	S31272	65[450]	29[200]	35
TP316	S31600	75[515]	30[205]	35
TP316H	S31609	75[515]	30[205]	35
TP316L	S31603	70[485]	25[170]	35
TP316N	S31651	80[550]	35[240]	35
TP316LN	S31653	75[515]	30[205]	35
TP317	S31700	75[515]	30[205]	35
TP317L	S31703	75[515]	30[205]	35
TP321	S32100	75[515]	30[205]	35
TP321H	S32109	75[515]	30[205]	35
TP347	S34700	75[515]	30[205]	35
TP347H	S34709	75[515]	30[205]	35
TP347LN	S34751	75[515]	30[205]	35
TP347HFG	...	80[550]	30[205]	35
TP348	S34800	75[515]	30[205]	35
TP348H	S34809	75[515]	30[205]	35
XM-15	S38100	75[515]	30[205]	35
...	S30615	90[620]	40[275]	35
...	S30815	87[600]	45[310]	40
...	S31050:			
$t \leq 0.25$ in.		84[580]	39[270]	25
$t > 0.25$ in.		78[540]	37[255]	25
...	S33228	73[500]	27[185]	30
...	S21500	78[540]	33[230]	35
...	S31725	75[515]	30[205]	35
...	S32716	80[550]	35[240]	35
...	S32615	80[550]	32[220]	25
XM-19	S20910	100[690]	55[380]	35
...	S25700	78[540]	35[240]	50
...	S32050	98[675]	48[330]	40
...	S34565	115[790]	60[415]	35

[A] When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimens with gage length equal to 4*D* (4 times the diameter) is used, the minimum elongation shall be 22 % for all ferritic grades except 18Cr-2Mo, T23 T24, T91, T92, and T911.

[B] For longitudinal strip tests a deduction from the basic minimum elongation values of 1.00 % for 18Cr-2Mo, T23, T24, T91, T92, and T122, T911, 1.50 % for all other ferritic grades for each 1/32-in. [0.8-mm] decrease in wall thickness below 5/16 in. [8 mm] shall be made.

TABLE 5 Computed Minimum Values[A]

Wall Thickness		Elongation in 2 in. or 50 mm, min, %	
in.	mm	18Cr-2Mo, T23, T24 T91, T92, T122, and T911	All Other Ferritic Grades
5/16 [0.312]	8	20	30
9/32 [0.281]	7.2	19	29
1/4 [0.250]	6.4	18	27
7/32 [0.219]	5.6	17	26
3/16 [0.188]	4.8	16	24
5/32 [0.156]	4	15	23
1/8 [0.125]	3.2	14	21
3/32 [0.094]	2.4	13	20
1/16 [0.062]	1.6	12	18
0.062 to 0.035, excl	1.6 to 0.9	12	17
0.035 to 0.022, excl	0.9 to 0.6	11	17
0.022 to 0.015 incl	0.6 to 0.4	11	16

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

T911: $E = 32t + 10.00$ [$E = 1.25t + 10.00$]. For all other ferritic: $E = 48t + 15.00$ [$E = 1.87t + 15.00$].

where:
E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in. [mm].

10. Hardness Requirements

10.1 *Ferritic Grades*:

10.1.1 Grades T5b, T7, and T9 shall have a hardness not exceeding 179 HB/190 HV (89 HRB). Grades T24, T91, T92, T122, and T911 shall have a hardness not exceeding 250 HB/265 HV (25 HRC). Grade T23 shall have a hardness not exceeding 220 HB/230 HV (97 HRB).

10.1.2 Grade 18Cr-2Mo shall have a hardness not exceeding 217 HB/230 HV (96 HRB).

10.1.3 All other ferritic grades shall have a hardness not exceeding 163 HB/170 HV (85 HRB).

10.2 *Austenitic Grades*:

10.2.1 Grades TP201 and TP202 shall have a hardness not exceeding 219 HB/230 HV (95 HRB).

10.2.2 Tubes fabricated from S30815,S31272, S31050, and S25700 shall have a hardness not exceeding 217 HB (95 HRB).

10.2.3 Tubes fabricated from TP310HCbN and S32050 shall have a hardness not exceeding 256 HB (100 HRB).

10.2.4 XM-19 (UNS S20910) shall have a hardness not exceeding 250 HB/265 HV (25 HRC).

10.2.5 Tubes fabricated from S34565 shall have a hardness not exceeding 241 HB (100 HRB).

10.2.6 All other austenitic grades shall have a hardness not exceeding 192 HB/200 HV (90 HRB).

11. Mechanical Tests and Grain Size Determinations Required

11.1 *Tension Test*—One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 3).

11.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot (Note 2).

11.3 *Flaring Test*—One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 2).

11.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 3).

11.5 *Hydrostatic Test*—Each tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

11.6 *Grain Size*—Grain size determinations, to demonstrate compliance with 5.2, shall be made on one end of one finished tube from each lot (see Note 2).

12. Hydrostatic or Nondestructive Electric Test

12.1 Each tube shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

13. Forming Operations

13.1 Tubes when inserted in the boiler or tube sheet shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

NOTE 4—Certain of the ferritic steels covered by this specification will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures, particularly the 4 to 9 % chromium steels. Therefore, operations that involve heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

14. Surface Condition

14.1 Ferritic cold drawn steel tubes shall be free of scale and suitable for inspection. A slight amount of oxidation is not considered scale.

14.2 Ferritic hot rolled steel tubes shall be free of loose scale and suitable for inspection.

14.3 Austenitic steel tubes shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

14.4 Any special finish requirement shall be subject to agreement between the supplier and the purchaser.

15. Product Marking

15.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include whether the tube is hot finished or cold finished. For Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, TP347HFG, TP348H, S21500, S33228, and S30815, the marking shall also include the heat number and heat-treatment lot identification. When either T2 or T12 are ordered with sulfur content higher than 0.025 but equal or less than 0.045, the marking shall include the grade with the designation, S; example T2S and 2S.

16. Keywords

16.1 alloy steel tube; austenitic stainless steel; boiler tubes; ferritic stainless steel; heat exchanger tube; high-temperature

applications; seamless steel tube; steel tube; superheater tubes; temperature service applications-high

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved annealed condition.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1500 to 1650°F [815 to 900°C] after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and supplier.

S2. Stabilizing Heat Treatment

S2.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP310HCbN, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S3. Unstraightened Tubes

S3.1 When the purchaser specifies tubes unstraightened after final heat treatment (such as coils), the minimum yield strength of Table 3 shall be reduced by 5 ksi [35 MPa].

S3.2 On the certification, and wherever the grade designation for unstraightened tubing appears, it shall be identified with the suffix letter “U” (for example, 304-U, 321-U, etc.).

S4. Intergranular Corrosion Test

S4.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S4.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S4.2 A stabilization heat treatment in accordance with Supplementary Requirement S2 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.